

# **Structured and Inhibited Mixing on the Continental Shelf**

Timothy F. Duda

Applied Ocean Physics and Engineering Department, MS 11  
Woods Hole Oceanographic Institution, Woods Hole, MA 02543  
Phone: (508) 289-2495 Fax: (508) 457-2194 Email: [tduda@whoi.edu](mailto:tduda@whoi.edu)

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## **LONG TERM GOALS**

Our goal is to understand diapycnal mixing process during the stratified summer season in the temperate continental shelf environment.

## **OBJECTIVES**

The objective of this project is to determine whether intermittent diapycnal mixing (i.e. turbulent) events are sensitive to the background conditions in a specific way. The hypothesis is that mixing will be more efficient in less-stratified layers than more stratified interfaces within a field of step-like density gradient. Such an effect would cause density-gradient perturbations to grow, an effect sometimes known as the Phillips instability because it was pointed out in a 1972 paper authored by O. M. Phillips. This behavior is analogous to a negative eddy diffusivity  $K$ . It would also cause effective eddy diffusivity, measured over scales large with respect to the step length, to be lower than the spatial mean value of the structured (gradient-dependent) diffusivity. Evidence of gradient-dependent  $K$  was found in the ONR Coastal Mixing and Optics (CMO) program dye diffusion studies, and in towed-microscale conductivity measurements obtained in conjunction with the dye studies (Duda and Rehmann, 2002). We wish to expand on the CMO work by obtaining more data of better quality than previously available, confirming and/or improving the result.

## **APPROACH**

We will measure microscale conductivity and supporting data with a towed sensor package. The submerged platform and the data-acquisition electronics are of our own design. Conductivity serves as a proxy for temperature in waters of uniform salinity. We intend to operate in such waters, or waters of nearly uniform salinity, which can occur on the south New England shelf after the winter mixing period, when surface warming causes rapid building of stratification.

The towed sensor package will have a Sea-Bird 9+ CTD sampling at 6 or 12 Hz and two Sea-Bird micro conductivity probes sampling at 400 Hz. Additional sensors at 6 or 12 Hz include bottom avoidance sonar and a 2-axis current meter at the front of the platform measuring the angle of attack of the sensors into the flow. Stable towing and low angle of attack will be essential. Pitch, roll and heading will be recorded at 2 Hz. The data will be packetized and sent to the tow ship, which will be equipped with an acoustic Doppler current profiler for shear measurement. The data will be merged with GPS navigation data in the main lab, and will be stored as well as examined in real-time.

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The conductivity gradient variance within short time intervals, which should be proportional to temperature gradient variance and to  $\chi$ , the thermal dissipation rate, will be compared to the vertical temperature gradient, also estimated over short time intervals. A correlation of the two quantities and a relationship shallower than  $\chi$  proportional to  $dT/dz$  to the first power would indicate eddy diffusivity  $K$  inversely proportional to the gradient. Such a relation, in agreement with the hypothesis discussed by Phillips (1972) and Balmforth et al (1998), among others, was found by us in a limited set of CMO microstructure data and recently published.

## **WORK COMPLETED**

The field program is scheduled for the summer of 2004. During FY03 we have been modifying and upgrading our system. A second microscale channel is being added to the system. The ship-board data archiving system does not allow adequate display of the data, and a real-time display and analysis software suite is being written. The hardware is to be assembled, software written, and the entire system tested in the remainder of 2003 and the first half of 2004. The data-acquisition system has been in storage since August 1997 and has been found to be functional, so that no unforeseen repairs are required.

## **RESULTS**

There are no results at this time. Data will be collected during a field experiment in FY04.

## **IMPACT/APPLICATIONS**

The application of these results will be in coastal circulation and transport modeling and prediction, and in chemical or plankton dispersal modeling. Water property modeling, of optical properties, for example, may benefit from more detailed understanding of diapycnal mixing processes and of layer formation processes.

## **TRANSITIONS**

The tow platform developed by us for this type of research has been used by Naval Research Laboratory personnel in conjunction with monostatic high-frequency flow-visualization acoustics to study nonlinear internal gravity waves.

## **RELATED PROJECTS**

The Sundermeyer/Ledwell/Lelong ONR PO project to study the effects of episodic mixing patches on lateral (isopycnal) dispersion seeks to study related effects on mixing of nonuniform density gradient fields and we intend to consolidate the results of the two projects.

## **REFERENCES**

Balmforth, N. J., S. G. Llewellyn Smith, and W.R. Young, Dynamics of interfaces and layers in a stratified turbulent fluid, *J. Fluid Mech.*, 355, 329-358, 1998.

Duda, T. F., and C. R. Rehmann, Systematic microstructure variability in double-diffusively stable coastal waters of nonuniform density gradient J. Geophys. Res., 107(C10), 3145, doi:10.1029/2001JC000844, 2002.,

Phillips, O. M., Turbulence in a strongly stratified fluid – is it unstable?, *Deep-Sea Res.*, 19, 79-81, 1972.